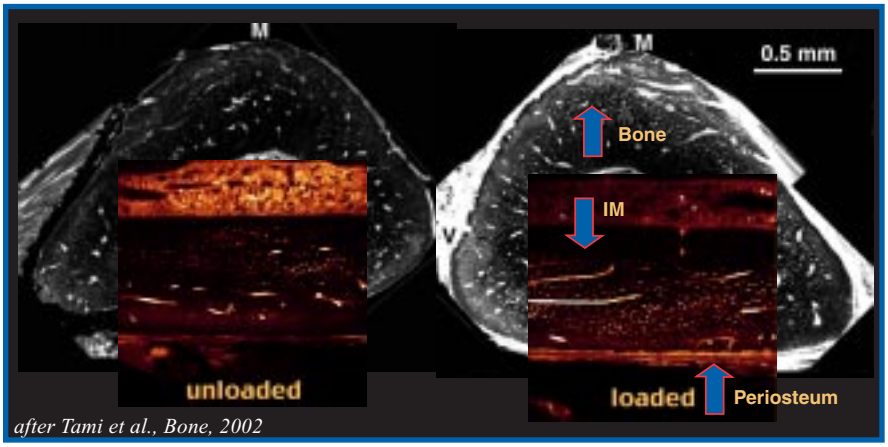
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio

John Glenn
Biomedical Engineering Consortium
Helping Astronauts, Healing People on Earth

Bone: Out With the Old, In With the New

Through the process of ultrasound therapy, which induces microdamage and natural rebuilding, it may be possible to maintain the bone mass of astronauts and people on Earth who suffer from osteoporosis.

It is known that astronauts lose bone mass at a rapid rate, between 0.5 and 2 percent of their bone mass per month while living in microgravity, or 6 to 24 percent per year. By comparison, women with Type I (hormone-related) osteoporosis lose 3 to 4 percent per year, and the loss rate is even lower in women and men with Type II (age-related) osteoporosis. Researchers are working to discover why this occurs, both to learn how to restore bone mass and how to prevent this bone loss altogether. With the support of the John Glenn Biomedical Engineering Consortium (GBEC), principal investigator Ulf Knothe of the Cleveland Clinic Foundation (CCF) and co-investigators Dwight Davy (Case Western Reserve University (CWRU)), Melissa Knothe Tate (CCF and CWRU), Jerry Myers (Glenn Research Center), and Stevan Streem (CCF) are investigating the use of ultrasound, a high-frequency acoustic energy, to both maintain and restore bone density and health in space.

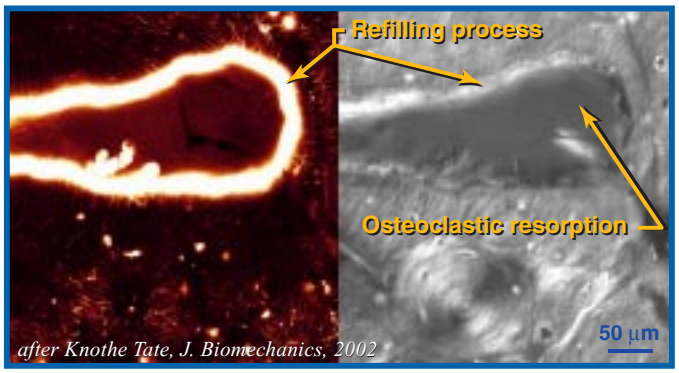


Fluid flow augments molecular transport through bone.

Human bone continually reweaves itself to stay strong. It is the only tissue in the body that repairs itself without scarring. In space, bone loses some of this natural ability to repair itself. The absence of gravity may hinder the normal wear and tear that switches on remodeling processes. On Earth, activity leads to tiny breaks within the bone's structure, or microdamage, which stimulates bone tissue to rebuild. Outside of a gravitational environment, something is needed to activate this biological trigger. The proposed device will expose the astronauts' bones to stimuli like those they are exposed to naturally on Earth. After low-level, diffuse microdamage of the bones is stimulated by ultrasound, the normal remodeling cycle will go into effect: cleaning out of old structure and the creation of new bone tissue.

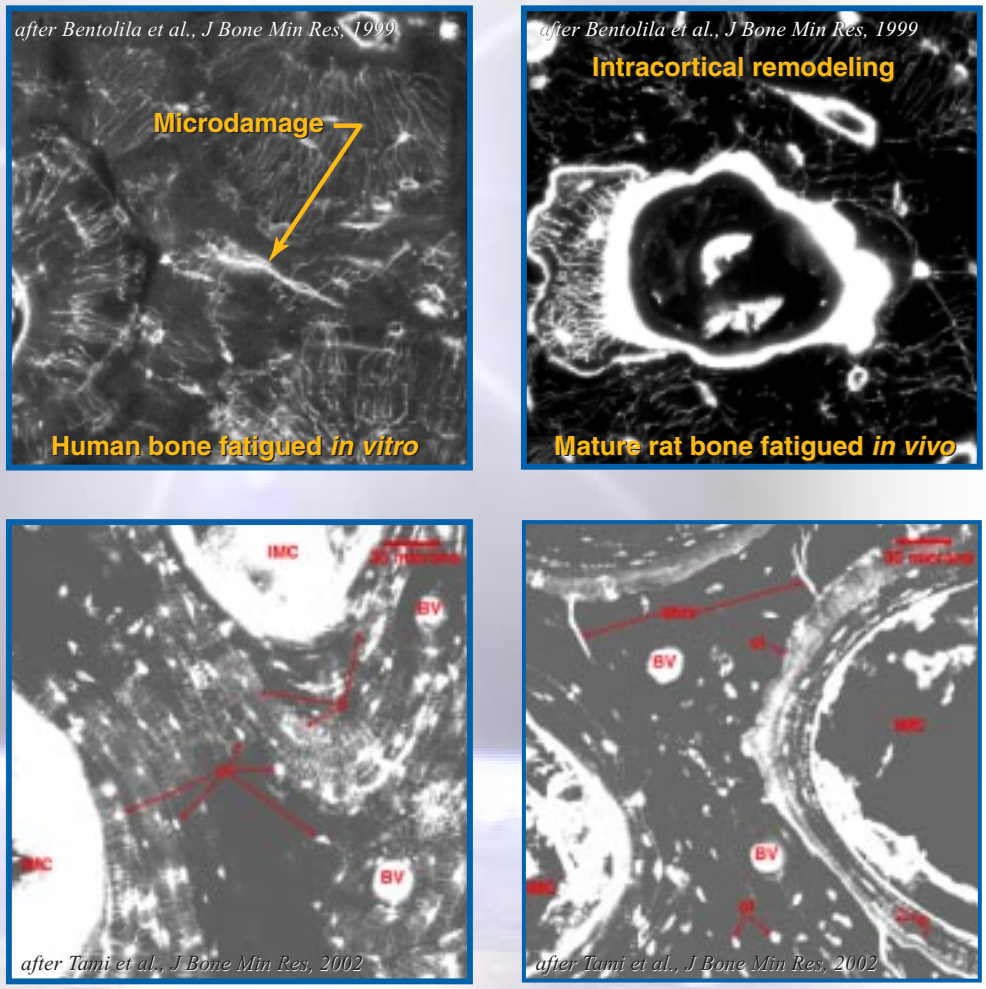
Ultrasound has been applied clinically and shown to be effective for the treatment of difficult-to-heal fractures (nonunions). Data suggest that this effect stems from an increase in fluid flow and mass transport of nutrients, minerals, and hormones to and waste products from the fracture site. Based on these data, the application of acoustic energy to strengthen bones and prevent bone loss in space seems logical. When designing the experimental device, researchers will identify the bandwidth and optimal application regime to produce the therapeutic effect.

An immersion system, analogous to a diving decompression chamber to avoid the development of the "bends", would be used to administer



As an effect of immobilization, osteoclasts remove bone. Upon remobilization, osteoblasts fill in the so-called cutting cones. It is expected that microgravity has an analogous effect on bone.

ultrasound treatments. Astronauts would use a space "recompression" chamber before or during exposure to microgravity conditions, which adversely affect the remodeling balance in bone. In recognition of size constraints, the chamber will surround only a single limb. To assure good transmission of the ultrasound treatment, a gel will be applied on the limb, as is done on Earth in some ultrasound treatments. When designing the experimental device, researchers will identify the bandwidth and optimal application regime to produce the therapeutic effect.



Impaired regional bone fluid flow secondary to matrix damage is a likely cause of impairment of osteocyte viability.

Benefits on Earth

If proven effective, this device would lend itself to the prevention of osteoporosis or age-related bone loss on Earth. Most older people have some degree of bone loss as they age. Osteoporosis can even affect people at younger ages, making daily life extremely difficult. Weight lifting has been tapped as a way to stimulate bone growth and strength. A new technique for bone reconstruction may also prove valuable in avoiding fractures that so often trigger a general decline in health.

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M–1043–04
May 02